



*... for a brighter future*

# *Dark Energy Survey Supernovae*

## *Report on SN Working Group Activities*

*Joe Bernstein<sup>1</sup>, Rick Kessler<sup>2,3</sup>,  
Steve Kuhlmann<sup>1</sup>, Hal Spinka<sup>1</sup>, DES  
Supernova Working Group*

*<sup>1</sup>HEP Division, Argonne National Lab*

*<sup>2</sup>KICP, U. Chicago*

*<sup>3</sup>Dept. of Astronomy & Astrophysics, U. Chicago*



U.S. Department  
of Energy

UChicago ►  
Argonne<sub>LLC</sub>



*DES Collaboration Meeting*  
*CBPF, Rio de Janeiro      2009-05-26*

# Outline

- DES-Supernovae (DES-SN) Overview
- SNANA: SN light curve simulation & fitter
- DES-SN Strategy Paper
- SNANA in the Infrared
- Summary & Conclusions



DARK ENERGY  
SURVEY



University of Chicago

## DES Supernovae

- DES time allocation fixes total supernovae (SNe) exposure time
  - 1260 hr planned (73% non-photometric) over 5-year survey
  - maximal use of non-photometric time (~920 hr) planned
- Time per field & number of fields can be simulation optimized
  - ultra-deep strategy (3 square degrees = 1 DES field)
  - deep strategy (9 square deg.)\*
  - shallow but wide strategy (27 square deg.)
  - hybrid strategy, e.g., 2 deep + 3 wide (15 square deg.)
- Results show hybrid strategy is best (more later)

\* Highlighted in DES DOE proposal

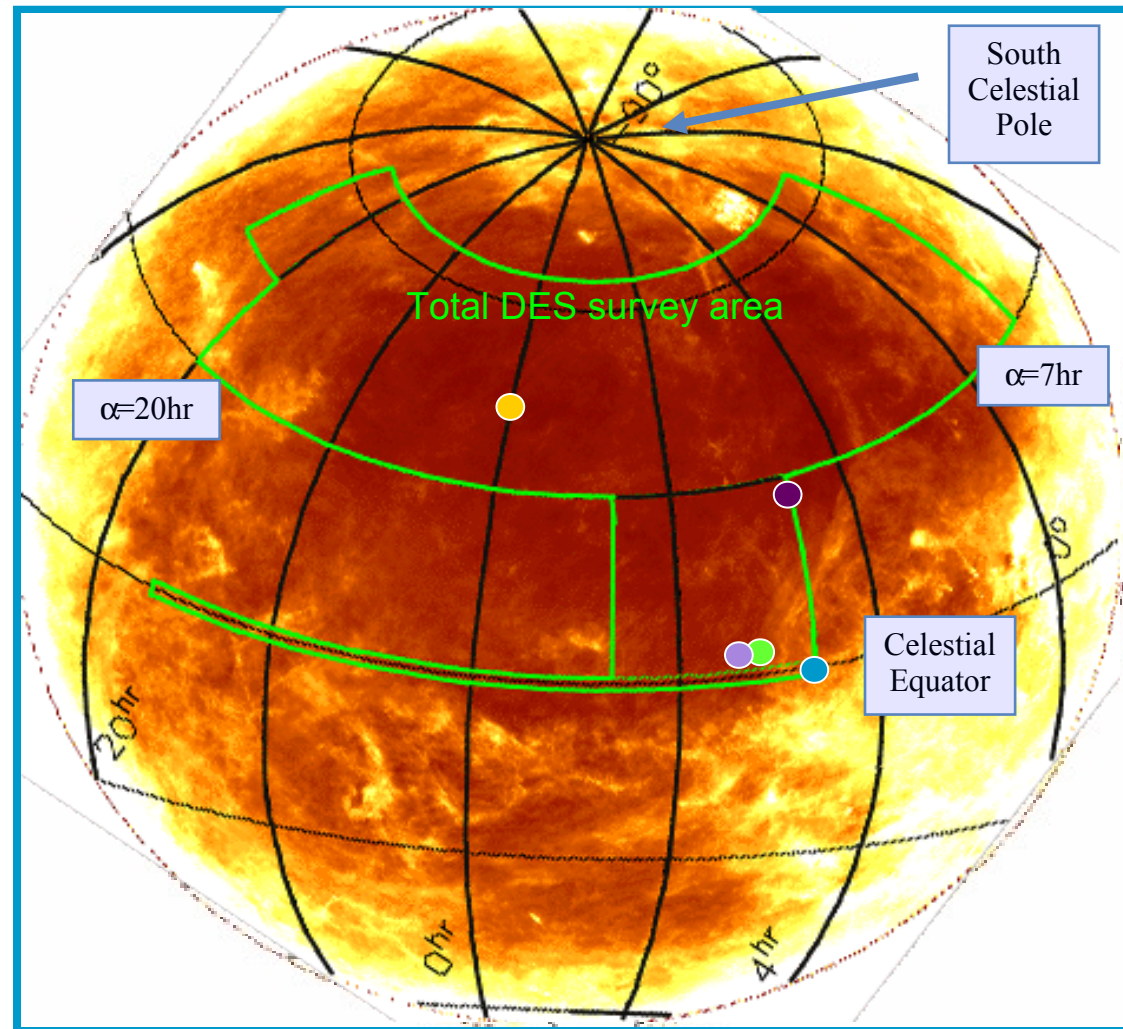
## Currently Favored DES-SN Fields

Chosen to maximize:

- visibility from DES site
- past observation history
- visibility from, e.g, Hawaii

Chandra Deep Field – South ●  
 Sloan Stripe 82 ●  
 SN Legacy Survey (SNLS) D1 ●  
 XMM-Newton LSS ●  
 ELAIS S1 ●

From a study by Peter Nugent



## ***SNANA: SuperNova ANalysis package for DES***

R. Kessler (U. Chicago), J. P. Bernstein, S. Kuhlmann, & H. Spinka (ANL)

- Also used by SDSS & LSST
- Software suite for simulating and fitting SN light curves
- Motivation was a more accurate and complete study of DES-SN capabilities including DES CCD and filter characteristics, CTIO sky fluctuations using Essence data inputs, dust extinction effects, etc.
- Uses various models (e.g., MLCS2k2, SALT-II, stretch, etc.)
- Models and fits both Ia and non-Ia SNe
- Public URL: <http://sdssdp47.fnal.gov/sdsssn/SNANA-PUBLIC/>  
(more aesthetically pleasing URL via sdss.org in works)





## Welcome to the SuperNova ANalysis software homepage

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Guide](#)[SNANA  
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**SNANA contains a light curve fitter and simulation that can be applied to any supernova (SN) model and to any data set. This website provides installation instructions, a user manual, and a software package download area.**





## SNANA Downloads

### Current Software Release

Downloads	Version	Description
<a href="#">SNANA.tar.gz</a>	v8_08	Source code (few MB)
<a href="#">SNDATA_ROOT.tar.gz</a>	2009-05-14	Data & input files, model parameters, etc. (> 1 GB)

[SNANA Software Archive \(directory listing only\)](#)

[Back to the SNANA Homepage](#)

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## *SNANA Description*

- Computes rest-frame model magnitudes using various models
- Applies random color/luminosity fluctuations
- Includes host galaxy dust extinction
- Applies K-corrections
- Offers a choice of cosmologies
- Applies Milky Way dust extinction via Schlegel maps\*
- Uses survey zero-points to convert magnitudes to flux
- CCD gain, noise, and sky noise added
- Fitter included for resulting light curves

\* Schlegel, Finkbeiner, Davis 1998, ApJ, 500, 525



# DES-SN Survey Strategy Simulations Paper



## Supernovae Simulations and Strategies: Application to the Dark Energy Survey (Draft: 03/28/2009)

J. P. Bernstein<sup>1</sup>, R. Kessler<sup>2,3</sup>, S. Kuhlmann<sup>1</sup>, R. Reis<sup>4</sup>,  
D. A. Finley<sup>4</sup>, J. A. Frieman<sup>2,3,4</sup>, A. G. Kim<sup>5</sup>, J. Marriner<sup>4</sup>, P. Mukherjee<sup>6</sup>,  
R. C. Nichol<sup>7</sup>, P. Nugent<sup>5</sup>, D. R. Parkinson<sup>6</sup>, M. Sako<sup>8</sup>, H. Spinka<sup>1</sup>. . .

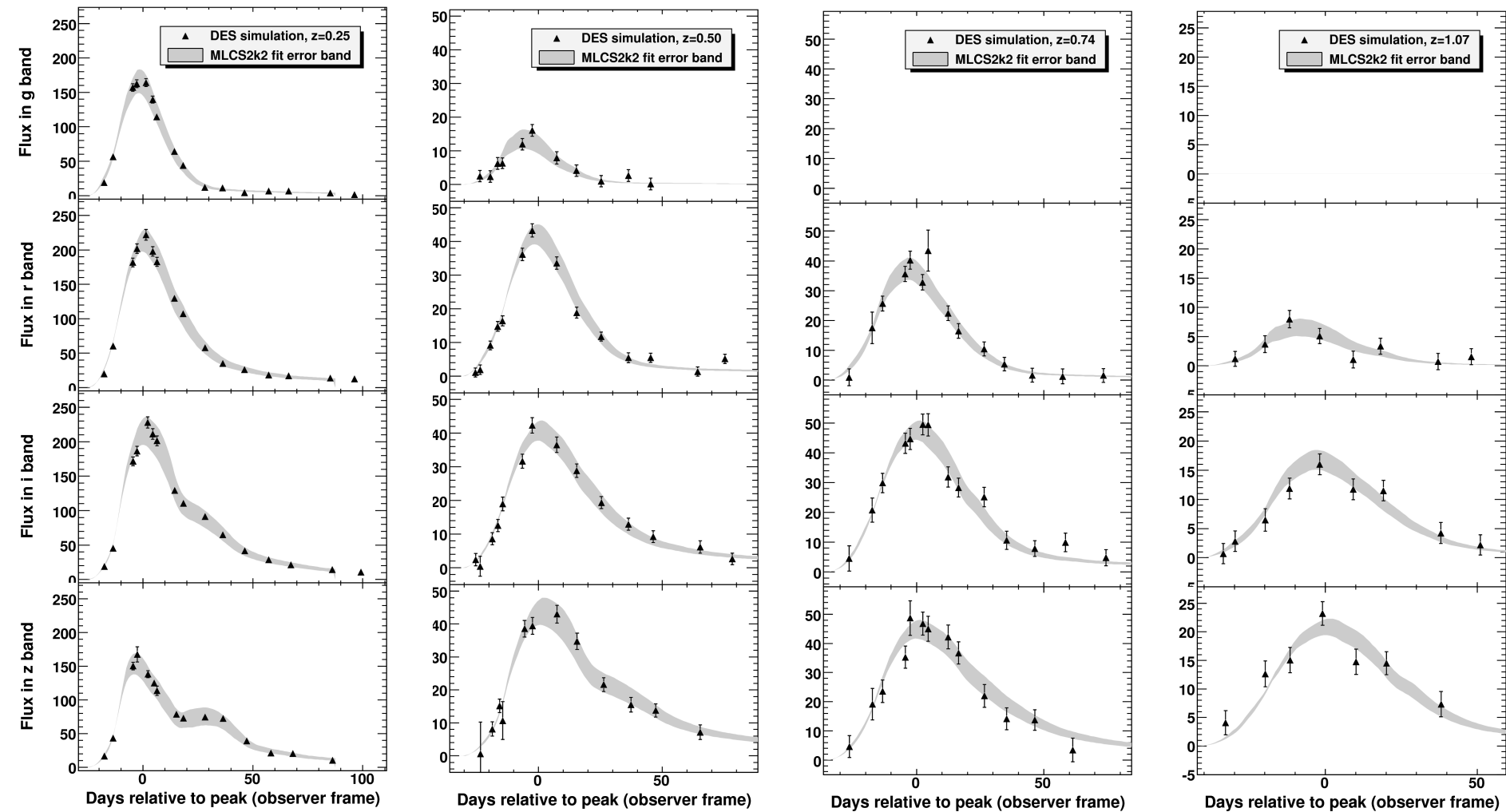
### ABSTRACT

We present an analysis of Type Ia supernova light curves simulated for the upcoming Dark Energy Survey (DES) supernova search. Employed is a code suite that generates and fits realistic supernova light curves in order to obtain distance modulus/redshift pairs which are passed to a cosmology fitter. We harnessed the fit results to investigate several different survey strategies including field selection, supernovae selection biases, and photometric redshift measurements. We forecast that the DES supernova search will discover on the order of 6000 Type Ia supernovae, with  $\sim 3000$  passing selection cuts, with planned full spectroscopic host galaxy follow-up out to a redshift of 1. Thus, the DES will provide by far the largest self-contained, high-redshift Type Ia sample to date, and will significantly improve  $z$ -band coverage relative to SNLS due to the heightened red sensitivity of the DES camera. Prior to obtaining host spectra, our analysis during survey operations will rely on photometric redshifts. Our simulations predict that for the DES, the distribution of photometric minus true supernova redshift will have a width of less than 3 percent and minimal non-Gaussian tails when the host galaxy photometric redshift is used as a prior. We further present estimates of 1) systematic effects on DES supernova observations and 2) the Dark Energy Task Force figure of merit.

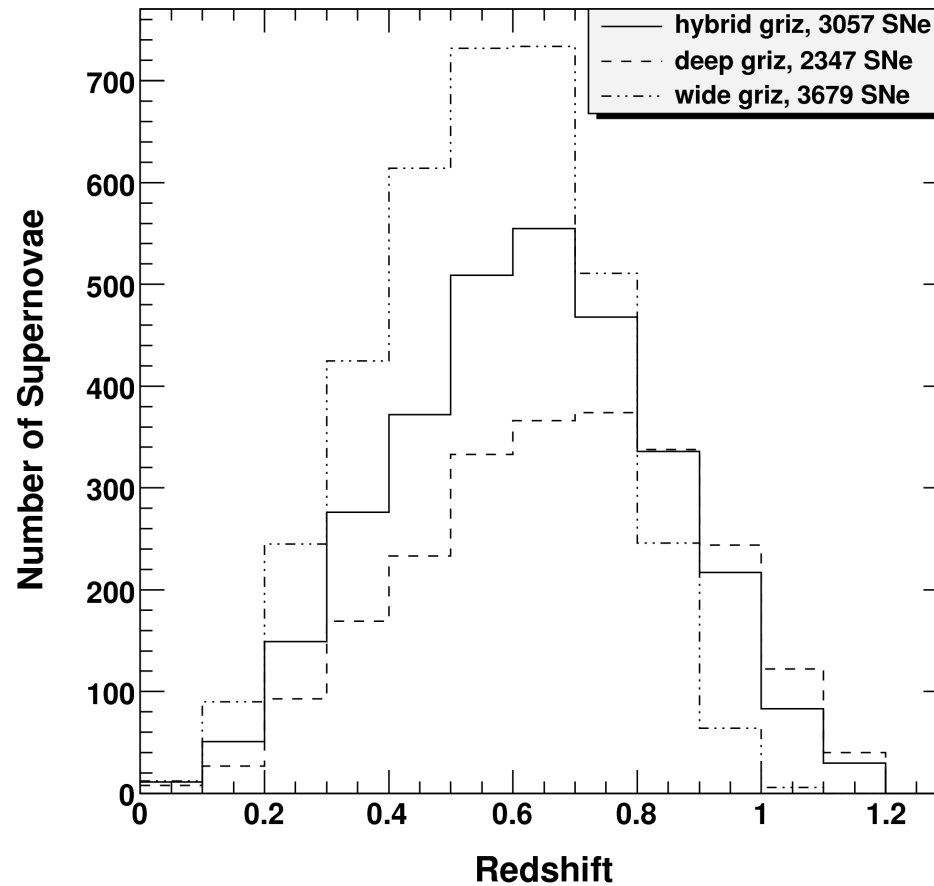
*Subject headings:* supernovae – cosmology: simulations

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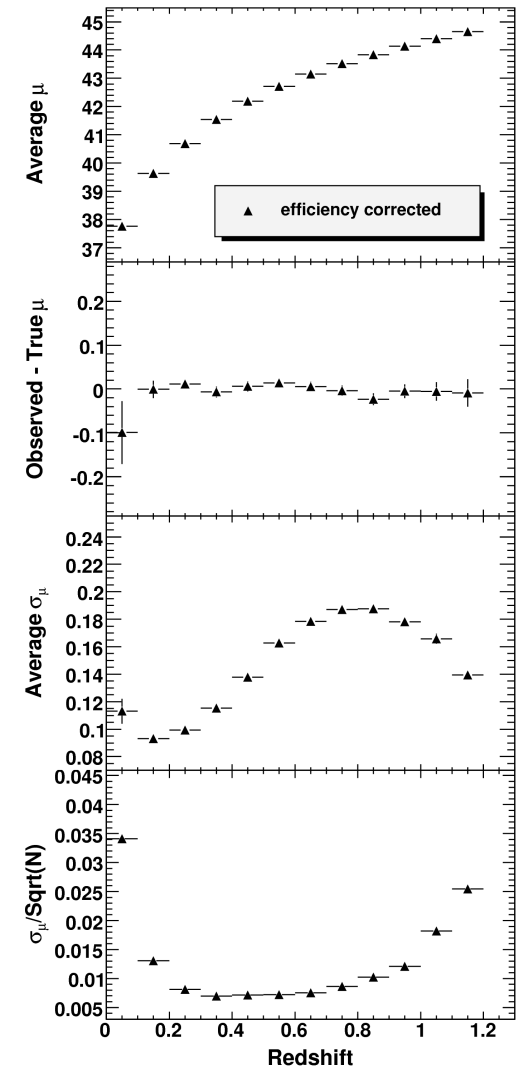
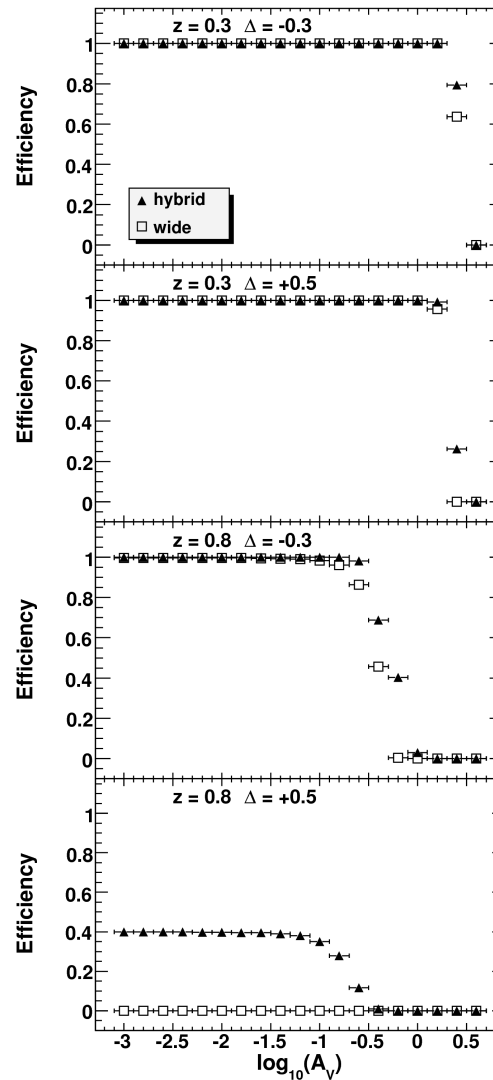
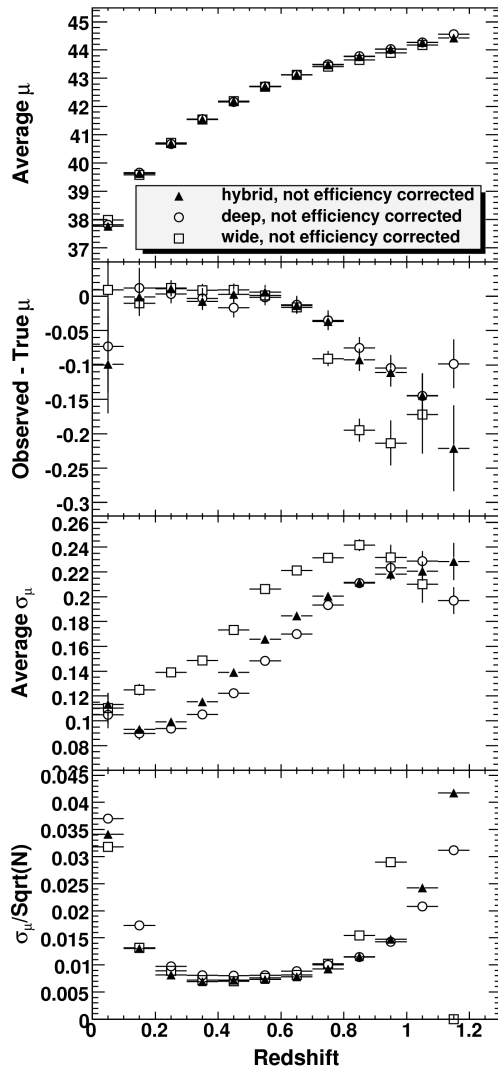
# Example DES SN Ia Light Curves



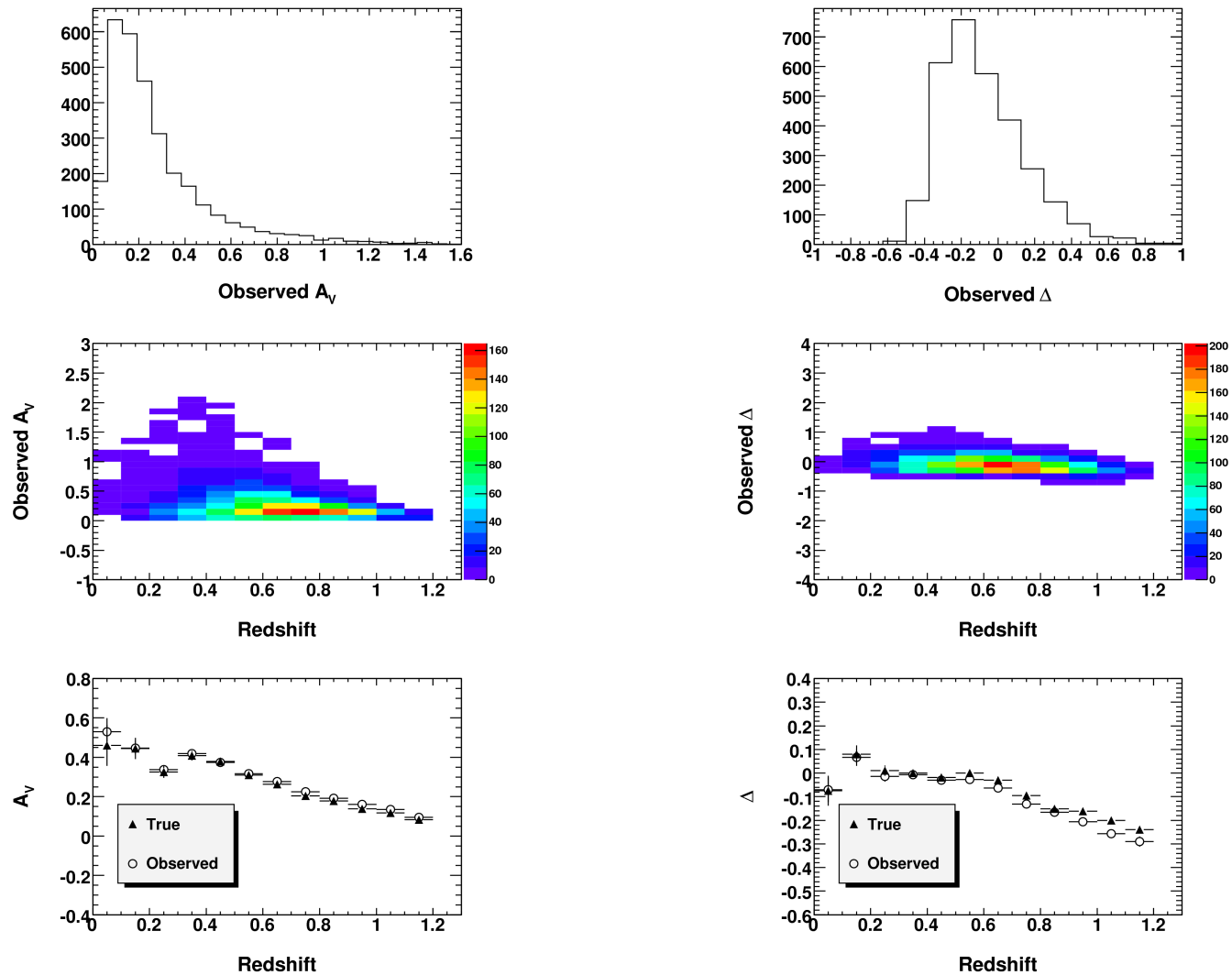
# Number Of Supernovae For Different Strategies



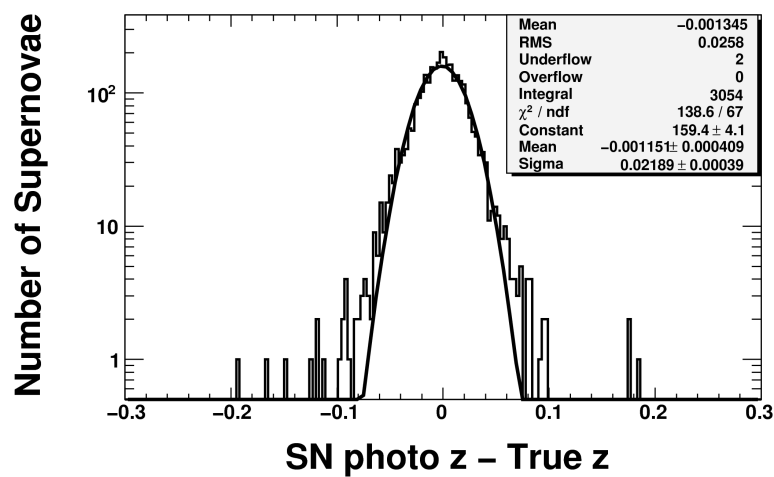
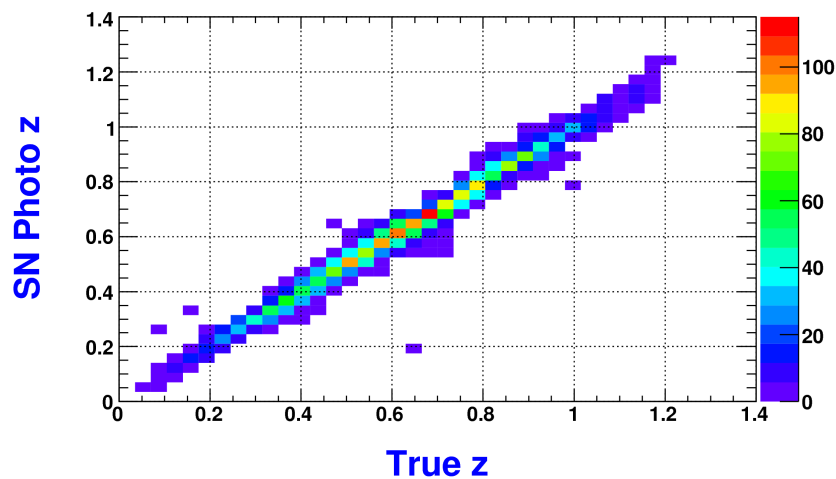
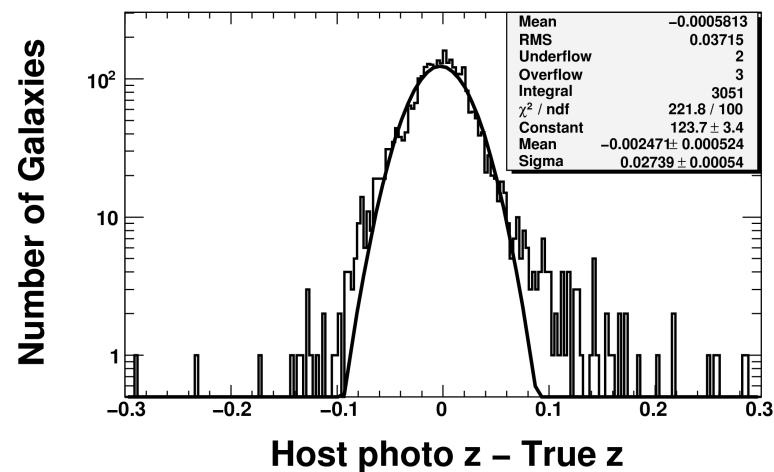
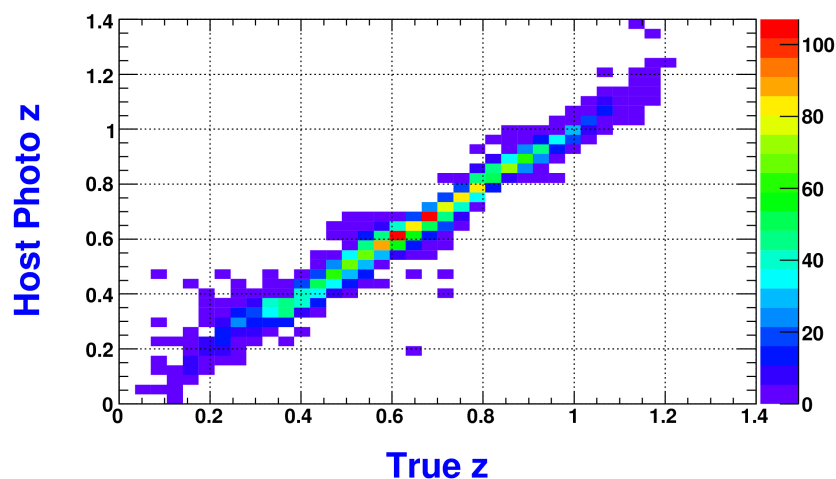
# Selection Bias And The Hubble Diagram Projection



# Extinction ( $A_V$ ) and Light Curve Shape Parameter ( $\Delta$ )



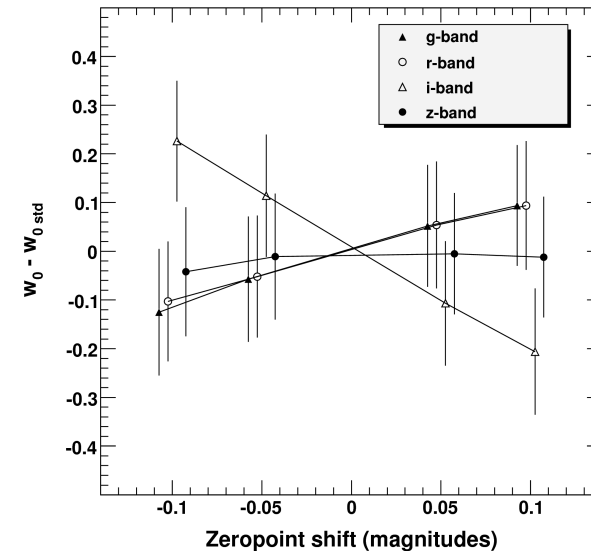
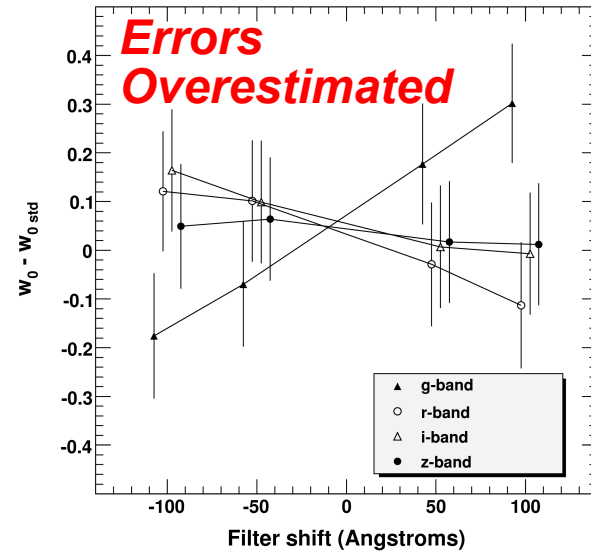
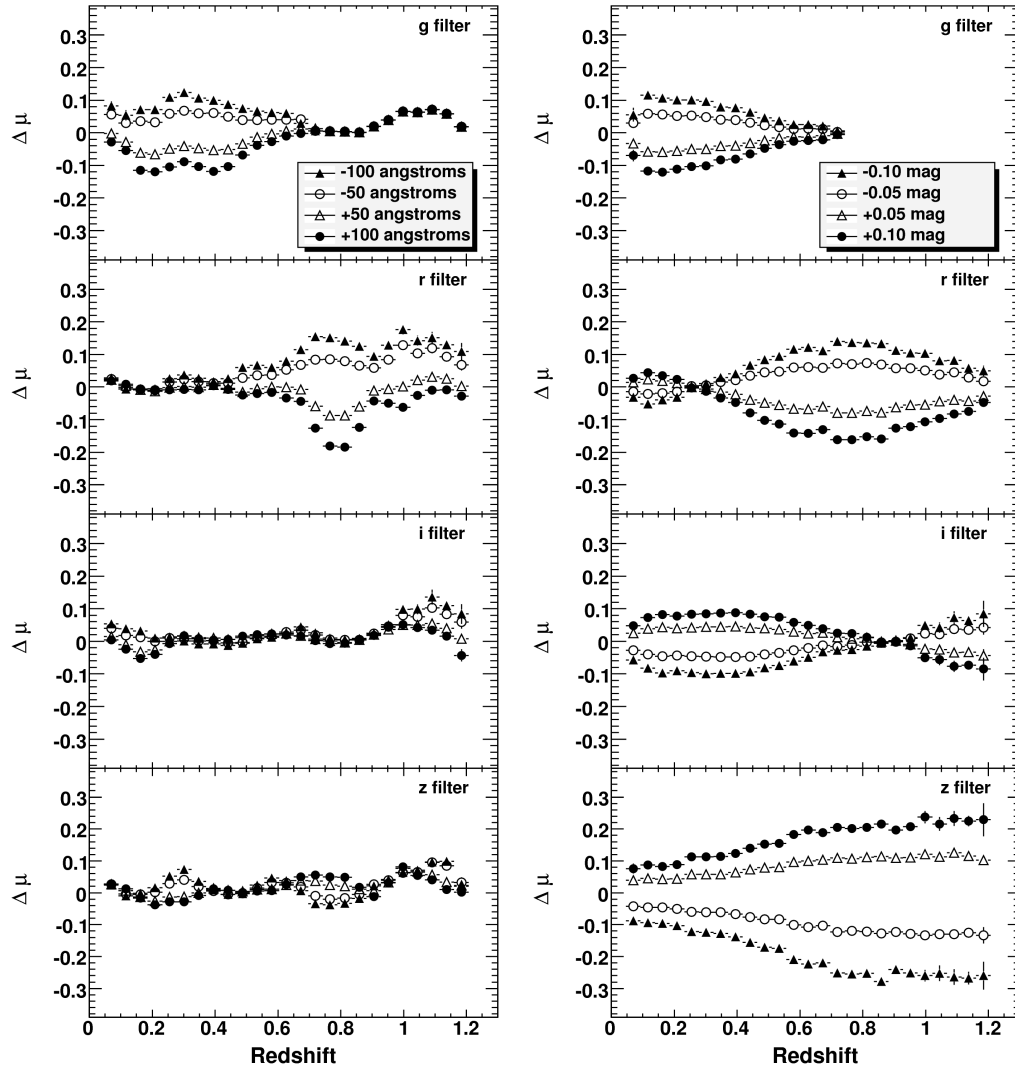
# Photometric Redshifts



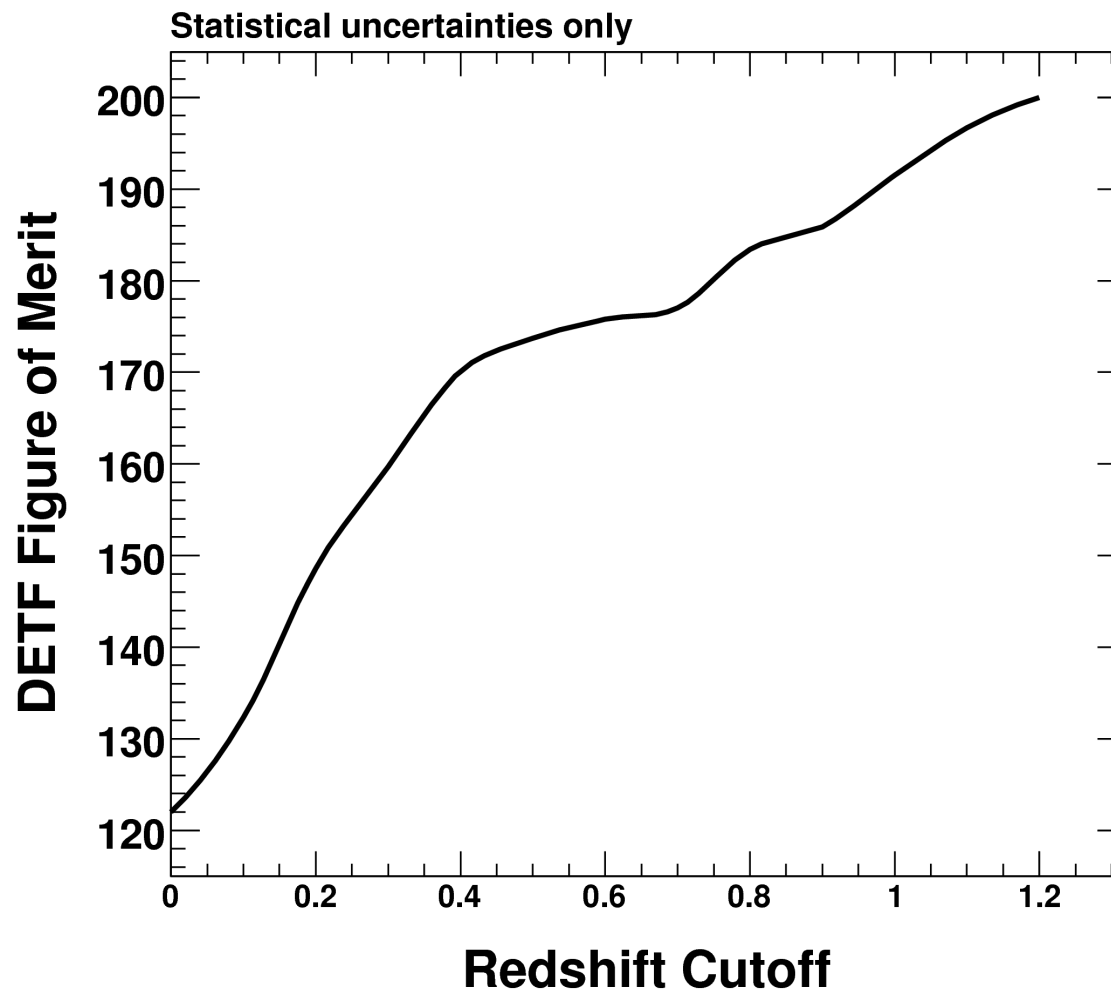


# Effect of Filter Centroid and Zeropoint Shifts

Study by Ribamar Reis



# Spectroscopic Redshift Cutoff and DETF Figure of Merit



## Completing The Paper

### ■ Extinction studies

- $R_V$ : from SDSS,  $R_V = 2.18 \pm 0.5$ 
  - fix  $R_V$  at one 1-sigma extreme & simulate, fix at other extreme & fit
  - see if causes a detectable effect
- $A_V$ : from SDSS,  $\tau = 0.334 \pm 0.088$ 
  - fix extreme  $\tau$  in  $A_V$  prior
  - see if fitter “figures it out”
- then, try in 0.1  $z$  bins and see if redshift dependence exists

### ■ Non-Ia contamination: see Steve Kuhlmann's talk (next!)

### ■ Infrared observation of DES-SN fields in YJHK by VIDEO survey

- VISTA telescope
- required extension to SNANA

## SNANA IR Simulations

- New IR model for SNANA: mlcs2k2.IR
  - UBVRIYJHK filters
  - uses UBVRI data from mlcs2k2.v006b
  - vectors by J. Marriner, currently -10 to +71 days only
  - uses new 9-filter genmag\_mlcs.c routine
  - UBVRI works as mlcs2k2.v006b if YJHK templates do not exist
- NB:  $A_V$ -prior dominates YJHK fits b/c sim has no lever arm on color
- IR sims & DES-SN sim paper
  - introduce VIDEO connection & show SNANA IR capability
  - branch full IR study off in separate paper
  - IR meaty subject (e.g., Alex Kim's preliminary IR SNR results)
  - allow for our new VIDEO external collaborators to be co-authors

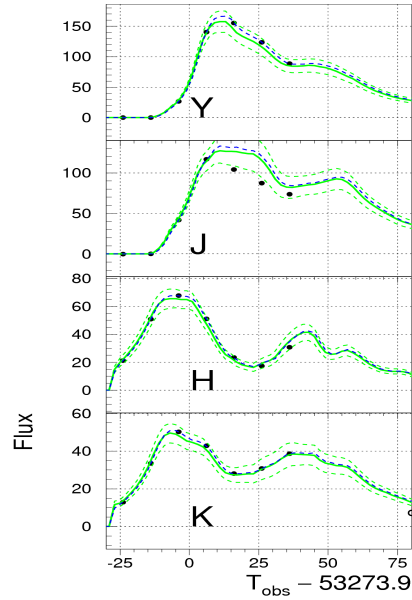
## SNANA IR Fitting Problem

- Y-band template was mistakenly identical to J-band template
  - caused overflows in AVwarp (+/- 6 magnitudes)
  - Rick Kessler's quick fix
    - used K-correction program to dump Y magnitudes vs. epoch using the Hsiao template
    - interpolated the peak mag-offset between I- and J-bands
    - warnings of AVwarp overflows added to SNANA code
  - still have overflows for VIDEO at late times (~ 50 days)
  - does not seem to be problematic so far
- Will address more formally moving forward
- Interesting note: IR fitting at  $<1$  sec/SN vs.  $\sim 1$  min/SN for griz

# First Try At “Perfect” VIDEO IR SN Ia Light Curves

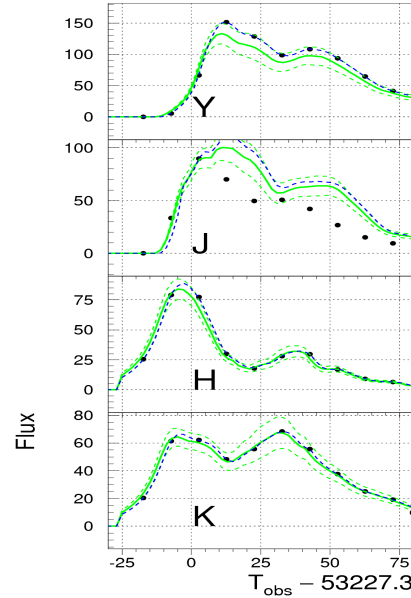
VIDEO VIDEO\_TEST SN 40031  $z=0.436$  YJHK

$A_V = 0.092 \pm 0.138$   $\Delta = -0.348 \pm 0.121$   
 $\mu = 42.091 \pm 0.105$   $\chi^2/\text{dof} = 54.1/24$



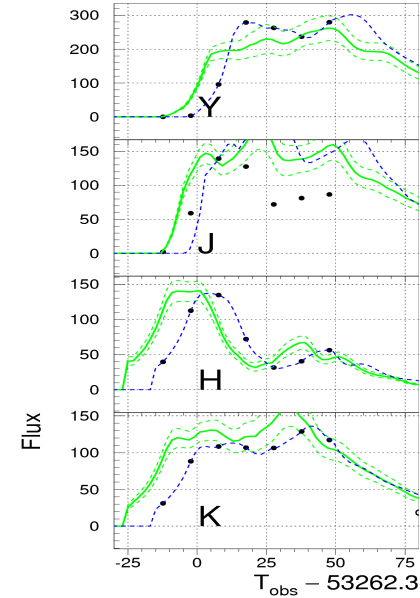
VIDEO VIDEO\_TEST SN 40032  $z=0.3362$  YJHK

$A_V = 0.509 \pm 0.222$   $\Delta = 0.205 \pm 0.069$   
 $\mu = 41.287 \pm 0.101$   $\chi^2/\text{dof} = 215.6/40$



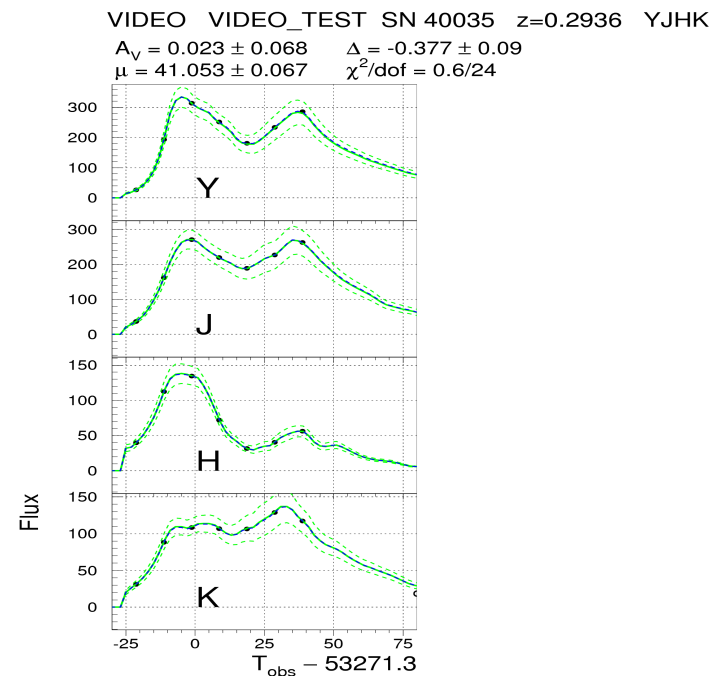
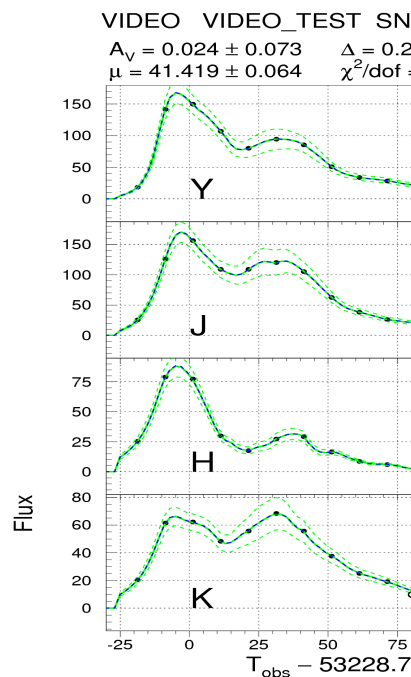
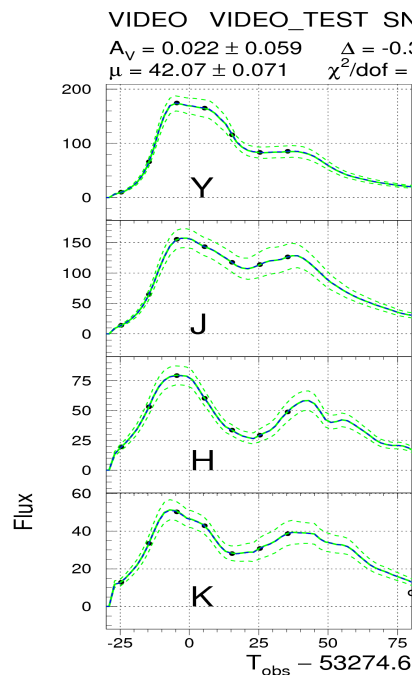
VIDEO VIDEO\_TEST SN 40035  $z=0.2936$  YJHK

$A_V = 1.902 \pm 0.333$   $\Delta = -0.736 \pm 0.099$   
 $\mu = 40.345 \pm 0.15$   $\chi^2/\text{dof} = 413.1/24$





# “Perfect” VIDEO IR SN Ia Light Curves After Y-template Fix



## *Summary & Conclusions*

- DES will compile a sample of  $\sim 3000$  well-measured SNe to  $z \sim 1$
- Hybrid strategy of “deep” and “wide” fields optimal
- DES-SN Strategy simulation paper advancing
  - systematics, non-Ia, and IR studies will complete paper
  - journal submission planned this summer
- Initial SNANA IR model in place
- Follow-on DES/VIDEO IR SN paper next